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AN ASSESSMENT OF KROMEKOTE CARD DEPOSITS FROM AERIAL SPRAY APPLICATIONS

by

K.W. Wallace
R. Jahren

SRC Technical Report No. 193

Publication E-906-1-B-87

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SUMMARY

Four sets of Kromekote deposit cards from aerial spraying of spruce budworm and Gypsy moth were analyzed. A literature review was undertaken to ascertain the many variables that influence the spray pattern deposits found. Aircraft speed, nozzle type and orientation, flying height and application rate, along with meteorological conditions all affect deposition and drift of chemical. Three of the four card sets had inadequate frequencies of drop deposits, likely due to inadequate calibration and characterization. Recommendations are made on the type and operating parameters that best suit forestry spray applications. Slow flying helicopters utilizing rotor downwash essentially push the spray onto the foliage. If a large forest area is to be sprayed it is recognized that fixed wing aircraft equipped with rotary atomization nozzles offer greater economic benefits. A VMD of approximately 100 microns along with 20 drops/cm^2 during calibration runs would likely balance the factors of drift and proper droplet size for effective insect control.

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LITERATURE REVIEW

1. Droplet Size and Coverage When Spraying Insecticides

The literature appears to have some uncertainty when one tries to determine which droplet size gives the best control while spraying insecticides. It would appear that a particular size of droplet could be specific to one insect and insecticide.

Fisher and Menzies (1976) concluded that the number of 215 μm droplets of carbaryl needed to immobilize the oriental fruit moth larvae (Grapholitha molesta) was a function of the number of contacts per cm^2 per time. In a short term exposure (60 minutes) as few as 10-20 contacts were sufficient to reach immobilization. The authors recommend that 35 drops/cm^2 were needed before larva obtained a lethal dose in a 3-4 minute period.

In another study, Jimenez et al. (1976) applied monocrotophos and water in mean drop sizes of 254, 396 and 556 μm to control the bollworm (Heliothis zea) in cotton. It has been generally assumed that smaller droplets provided better biological control, but no differences were found in damage to cotton plants using the above three drop sizes. In fact, yields were down when the smaller drop sizes were used.

Hall and Reichard (1978) investigated drop sizes in the range of 100-300 μm using aquaeous solutions of formetanate against the two spotted spider mite (Tetranychus urticae). The different drop sizes had little effect on the mortality rate even at two widely different application rates of 94 and 234 L/ha.

The differences noted above may be attributed to foliage coverage, insect size, meteorological conditions (temperature, relative humidity, wind speed and atmospheric stability), insecticide potency and increas-

ing concentration of active ingredient in evaporating droplets. Many factors influence the droplet spectra from the time of formation until the point of deposition.

Several authors have supported the view that smaller droplets are more effective against insects. Allen et al. (1975) found that 120 μm droplets gave better control of red spider mites than did 180 μm droplets when spraying captan in an apple orchard.

One of the specific target pests of interest in this study is the western spruce budworm (Choristoneura occidentalis) (Freeman). Barry et al. (1977) reported that evaporated droplets and dry aerosols of less than 50 μm diameter impacted on the budworm with the highest efficiency.

Sundaram et al. (1986) used a novel approach to simulate fir needles for the collection of mexacarbate. The authors agreed the size range of interest in fir foliage was 20-60 μm and substituted aluminum wire of the same diameter as one year old fir needles as the collection medium. Other commonly used techniques, e.g. Kromekote cards and dyed (Rhodamine B) tank formulations were used to access the ground deposits. The range of drops deposited on the Kromekote cards was 1.4-16 droplets/cm^2 for the water-based spray with a VDM range from 28-43 μm. The authors concluded that mean values of ground deposits could show an overall trend in average values of crown deposits from a full spray block.

2. Factors Affecting Aerial Spray Distributions from Fixed Wing Aircraft

Cadogan et al. (1986) have shown that Micronair AU3000 rotary atomizers used with both oil and water-simulated formulations produced adequate depositions on Kromekote cards for pest control. The aircraft

used was a Cessna 188-B Ag Truck, identical to the type used in the Paul Lake Provincial Park study (B.C. Forest Protection Branch). Drops/cm^2 and VMD's ranged from 4.5-12.7 and 123-147, respectively, under application conditions close to those used at Paul Lake Provincial Park. The decrease in drops/cm^2 and VMD at downwind distances of 90-500 m was 0.49-0.72 and 11.8-105.6 μm respectively.

The conventional flat-fan and disc-core type of nozzles produce a droplet spectrum with a wide range of drop sizes. In order to reduce the spectrum of drop sizes rotary nozzles have been used, which produce a more monodisperse drop size.

Picot et al. (1985) compared the Teejet 11010, Beecomist 360, and Micronair AU3000 nozzles (the later two are rotary types) in a wind tunnel with the aid of a laser spectrometer (PMS system). The laser system measures actual droplets in flight rather than deposited droplets on flat substrates. The former technique is a more accurate evaluation, as the effect of evaporation of smaller droplets (<100-150 μm) greatly influences the deposit pattern found on flat card surfaces. The Beecomist atomizer produced 97% of its volume in the 15-55 μm drop size range; for this reason it would be an ideal choice for spruce budworm control in fir and spruce. Unfortunately the output of the Beecomist is severely limited and as flow rates are increased the droplet size increases. The delivery rate of the Beecomist was 1/10 that of the Micronair nozzle. Therefore, unless concentrated insecticide can be sprayed its use may be ruled out.

Yates et al. (1983a) have designed an experimental aerodynamically shaped nozzle that emits droplets from pulsed laminar micro-jets. In their study, the fraction of droplets <219 μm diameter was designated as

a good indication of the potential drift hazard. Aerial tests with a D6 nozzle without a core showed very low drift potential, (with 0.58% of volume <219 μm) but the coverage would be extremely ineffective with a VMD of 1406 μm.

Yates et al. (1983a) have adopted the ASTM definition of "Relative Span" used as a nondimensional index of the uniformity of drop spectra. The designations $D_{v0.1}$, $D_{v0.5}$, and $D_{v0.9}$ represent the drop diameter such that the cumulative percent of the spray volume is 10%, 50% and 90% respectively, i.e. the VMD = $D_{v0.5}$. As most atomizers produce a non-Gaussian distribution, the standard deviation may not be the most appropriate way to compare them. The "Range" = $D_{v0.9}$ - $D_{v0.1}$ gives the variation in particle size that encompasses 80% of the spray volume, and the relative span is this range divided by $D_{v0.5}$.

The relative spans from the D6-45, D6-46 and the D6 nozzles in Yates et al. (1983a) study were relatively broad, ranging from 0.83-1.07 but the experimental pulsed micro-jet nozzles gave relative spans of 0.21-0.62 under different test conditions. The lower relative spans are indicative of a more monodisperse droplet spectrum which would have fewer droplets that are driftable and yet maintains good coverage characteristics (the ideal case).

The VMD of a standard 8004 flat fan nozzle (276 kPa) mounted on a Dehavilland "Beaver" aircraft has been shown to vary over the range of 164-304 μm (Yates et al. 1983b). This range of drop sizes resulted from three air speeds (145, 166, 177 km/hr) and nozzle angles relative to the airstream of 0°, 90° and 135° (back, down, and 45° forward and down). This points out the large range of drop spectra a single nozzle can produce using various speed and nozzle orientations. Two commercial for-

mulations of Bacillus thuringiensis (Dipel and Thuricide) were tested at various concentrations.

The above study shows how increasing the angle of the nozzles relative to the airstream produces a finer VMD for a given air speed. Through the choice of proper nozzle orientations and air speeds, one can adjust to the most effective VMD. Other factors to be taken into account are: the prevailing weather conditions at time of spray, aircraft height, formulation properties and the type of canopy.

It has been shown (Yates et al. 1985) that as the $D_{v0.5}$ decreases the drift potential increases in a expodential manner. In the same study drop distributions from four 80° flat-fan nozzles and nine combinations of disc and/or cores were measured in a wind tunnel to simulate aircraft speeds. A PMS laser system scanned the droplet output giving a representative temporal sample of the entire pattern. Some interesting observations regarding the spray uniformity can be made from the 84 different tests conducted. If the $D_{v0.5}$ is less than approximately 200 μm the relative span is normally less than 1.0, indicating a narrower spectrum of drop sizes, and correspondingly as $D_{v0.5}$ increases the relative span increases, indicating more divergence in the drop spectrum.

Yates et al. (1985) concluded that droplet diameters in the 30-150 μm range would pose the most serious drift hazard, therefore it is useful to tabulate the fraction of droplets less than 150 μm in a given distribution.

After selection of the appropriate fixed wing aircraft, nozzle system, and aircraft speed for delivery of the correct droplet size one must consider the best approach to traversing the spray area. Roth et al. (1985) have identified three characteristic non-symmetrical distri-

bution patterns for aerial applications. Improvements in pattern-edge disturbances and offset symmetric patterns are accomplished by flying in a race track or round robin pattern as opposed to the common back and forth pattern. Although this would improve the distribution pattern it may prove quite difficult under forest spraying conditions where flagmen or marking devices are difficult to use.

Johnstone (1971) has combined meteorological records and a simplified graphical analysis of sedimentation and wind transport of droplets in order to predict optimum drop sizes for low volume, (LV) 20-50 L/ha, and ultra-low volume (ULV), 1-5 L/ha, insecticide sprays. For non-aqueous sprays he suggests a VMD of about 100 μm is preferred. The product of aircraft height (H) and wind speed (U) should not be greater than 5 m^2 per second; the maximum flying height is 5 m under calm conditions while the minimum safe operating height should be 2 m.

The evaporation of aqueous sprays, particularly below 150 μm, can be quite severe. Johnstone (1971) has measured losses of 18, 35 and 50% at VMD's of 150 μm under conditions of 32°C and 46% relative humidity. The choice of VMD here would be 200 μm with an accompanying value of HU = 10 m^2/sec. Again the maximum flying height would be 10 m in calm winds or 2 m at U = 5 m/sec. The swath width should not be greater than 20 m for either LV or ULV application. These recommendations were made for aerial application of insecticides to cotton fields.

3. Factors Affecting Aerial Spray Distributions from Rotary Wing Aircraft

Helicopters generally require a higher initial cost and more maintenance than fixed wing aircraft, and this has resulted in a reduced usage in aerial spraying. Higher productivity can be achieved by using

the helicopter especially in cases where reduced volumes can be applied and wide swaths employed, e.g. orchards and vine spraying (Akesson 1974).

Johnstone et al. (1974) suggested that a 140 μm VMD and slow flying helicopter (40 km/hr) most effectively utilized the rotor downwash to push the spray through the canopy. One extremely important factor in helicopter spraying which does not exist in fixed wing aircraft is rotor downwash. The downwash velocity decreases in proportion to the increasing air speed; as well, the downwash velocity is larger in magnitude for heavier helicopters (Parkin 1979).

In one study (Johnstone 1961) rotor downwash has been shown to give good deposits on underleaf surfaces, while in another study (Johnstone 1962) the effect of underleaf coverage was greatest with sprays of 180 μm VMD. The author reported that at speeds greater than 23 km/hr the rotor downwash ceases to provide significant underleaf coverage, and the deposit patterns differ little from those for conventional, fixed wing aircraft. The deposits on vertical, rigid targets exceeded those on horizontal targets due to the higher lateral speeds of the droplets.

Yates et al. (1968) reported that lower forward speeds may produce higher deposits of spray on obscure areas (under surfaces of twigs, blossoms, etc.) when spraying a peach orchard by helicopter. The slower speed trials (29 km/hr) produced higher residues on both top and bottom surfaces in the central part of the pattern. The slow speed trial produced the strongest downwash (15 km/hr) and upwash (13 km/hr) velocities.

Several important conclusions emerge from the work of Parkin (1979) when using helicopters to spray. Generally, at speeds greater than 40

km/hr there is little vertical penetration or underleaf coverage. At the other end of the spectrum, at velocities of approximately 100 km/hr asymmetry occurs in the rotor wake and an asymmetric nozzle layout is required for an even distribution. In cases where drift is a major factor, boom length should not extend beyond the rotor diameter as this would place spray in the upward moving part of the vortices. In order to place the spray into the highest velocity portion of the rotor wake, rear and mid mounted booms are recommended.

4. The Effect of Meteorological Conditions in Aerial Application

The four main factors of concern when one is evaluating spray deposition and drift especially from aqueous sprays, are: wind speed (at 2 m), temperature, relative humidity and some measure of atmospheric stability (Maybank 1984).

In aerial spraying, especially in some forestry work the flying height is usually several tens of metres. Since the wind speed increases with height the best time to spray would be in periods of light or calm winds (early morning). Picot et al. (1986) recommend conditions of neutral stability and low winds as the best time for aerial application in coniferous forests. The authors point out that stable (10°C/km) and unstable (>10°C/km) conditions give elevated effective droplet release heights, the first due to buoyancy while the second is due to vortex breakup caused by turbulence. The authors also recommend that the droplet spectrum should be 15-55 μm (after evaporation) in order to reduce off target drift.

The factor of droplet evaporation plays a key role in aerial application. For example, a 100 μm droplet totally evaporates in 14 sec at

27°C and 50% relative humidity (Maybank 1969). If one takes the terminal velocity of the droplets and the release heights along with the wind speed, a simple calculation yields drift distance. The drift distances for 200, 100 and 50 µm diameter water droplets are: 4.2, 11.5 and 43 m respectively for a release height 3 m, and a wind of 3.6 km/hr. A 50 µm diameter spray droplet composed of water and chemical would quickly evaporate to a very concentrated, small droplet prone to greater drift.

Yates et al. (1981) measured evaporated droplets collected at 15, 46, 120 and 400 m downwind of an aerial application. The VMD's at the above mentioned distances were: 400, 200, 100 and 50 µm, respectively. They concluded that droplets in the 30-150 µm range posed the greatest drift hazard from aerial application over farmland.

When dealing with forestry spray, particularly of B.t. the smaller droplets (20-60 µm) appear to have the highest retention on conifer needles. If one were to emit a spray with a VMD of approximately 100 µm, the droplets would have sufficient energy to break-up and redistribute to smaller sizes. It would, therefore, appear appropriate to aim for a VMD of approximately 100 µm for adequate coverage of conifer needles.

MATERIALS AND METHODS

Five sets of rhodamine B dyed Kromekote cards were analyzed for spread factor and drop densities. Sets 1 and 2 were calibration runs for gypsy moth erradication, carried out at the Chilliwack Armed Forces Base. Set 3 was not analyzed because there was too little contrast between the background and the droplet image to allow detection. Sets 4 and 5 were calibration runs for western spruce budworm, carried out at the Kamloops Airport (set 4) and Paul Lake Provincial Park (set 5).

Before image analysis of the Kromekote cards could be undertaken, the spread factor (ratio of drop diameter to stain diameter) for each particular formulation was determined. The two types of commercial formulations of Bacillus thuringiensis (B.t.) were, used Dipel 88 (sets 1 and 2) and Thuricide, 38% (sets 4 and 5).

A droplet generator (Slack 1984) produced drops of a similar size to those in the field. Formulations from the test runs were used to produce drops on the blank Kromekote cards. A brief description of the drop generator follows: to generate droplets a needle is immersed in the pendant drop containing the solution of interest. A loudspeaker hooked up to the needle is driven by varying signals, this results in pulling the needle out of the fluid at varying speeds. A ligament is produced which decays into a droplet, and the size is determined by stroboscopic photomicrography. For water based droplets the range of possible sizes is approximately 175-600 μm.

The stains produced on the Kromekote cards were counted using the Cambridge Instruments Ltd. Quantimet 970 Image Analysis System. The standard software for this machine is the QUIPS system, version V05.00. Two image frames were counted on each card, representing a total area of

11.36 cm^2. Each image frame consisted of a circular area with a radius of 1.33 cm. The approximate centre of each area counted may be obtained by extending the vertical, horizontal or diagonal lines at the borders of each card. The calibration factor that converts the pixel size on the camera to the actual size was: 1 pixel = 44.84 μm. All the stains were counted with a roundness factor of 1.50 or less. The roundness factor takes into account the non-circular shape of some stains and at the above setting all the images in a frame were counted. The exception would be those stains when converted to drop diameters that were less than 50 μm (drop diameter). The reason for this choice of cutoff diameter results from there being too little contrast between the dyed stains and the paper surface. In order to obtain darker images a photocopy was made of each Kromekote card and the resultant copy counted. The smallest detectable image is 44.84 μm stain diameter or 25 μm drop diameter (set 5), 25.89 μm (set 4) and 29.46 μm (sets 1 and 2). The Quantimet 970 can detect black and white contrast extremely well. The photocopy produced small black spots from any dust or irregularities on the glass surface; as well, irregularities in the paper surface sometimes show up as counts in the extreme lower sizes. For these reasons the lowest size chosen was 50 μm (drop diameter). The error introduced would contribute a negligible amount to the VMD, and a slightly greater error to the NMD.

The numbers of individual stains were counted and converted to drop diameter size classes. Normally the size classes started at 50-100 μm drop diameter, unless there were none in that range, whereupon the size classes were adjusted to reflect the counts. Increments of 50 μm (drop diameter) were used up to a maximum of approximately 600 μm unless the

distribution required higher classes (set 1). The number of drops and the volume (calculated using the mid-point) were accumulated by percent in each size class and the number and volume median diameters as well as the number of drops per cm^2 calculated. The calculations were performed using the Lotus 1-2-3 software package on an IBM-PC.

The results for each card were added together in order to obtain the overall results for each set. A graph of cumulative (volume or number) less than the stated drop diameter (upper class limit) was constructed as a pictorial representation of the distribution.

In order to calculate the range ($D_{v0.9}$ - $D_{v0.1}$) and the relative span (range ÷ $D_{v0.5}$) the size of drop at the 10 and 90 cumulative percent levels were recorded from the graphs, providing a measure of the uniformity of the droplet distribution.

RESULTS

Table 1 gives a summary of the aircraft and meteorological conditions at the Chillwack Armed Forces Base (sets 1 and 2), Kamloops Airport (set 4) and Paul Lake Provincial Park (set 5). In order to fully evaluate the recovery deposits one must know the height of release and the wind speed (Johnstone 1971). Similarly temperature, wind speed and relative humidity are essential items to measure during aerial spray operations in order to comment on deposits and potential drift. The nozzle orientation has a definite bearing on the droplet size produced as Yates et al. (1983b) have pointed out, the air speed coupled with different nozzle orientations producing VMD's ranging from 164-304 µm with the same 8004 flat-fan nozzle.

Table 2 provides data on the droplet sizes for the various tests. The most important parameters are the VMD, NMD and a measure of the uniformity of the distribution (relative span). The coverage, as indicated by the number of drops per cm^2 is especially important for insect mortality (Fisher and Menzies 1976). One could recalculate this column to read number of contacts per insect area, but of course this would depend on foliage and placement of the Kromekote cards. The recovery column compares the actual application rates to those calculated from the drop count data. The comparison shows how much material was collected under the various field conditions. The column heading, spread factor, simply gives the variation of drop to stain diameters for various formulations using Kromekote cards. The spread factors were calibrated over the range of 155-560 µm drop diameter for sets 1 and 2, and 290-505 µm for sets 4 and 5.

Figures 1 to 8 give a pictorial depiction of the cumulative percent

Table 1. Aircraft and Meteorological Parameters.

Set	Date	Type	Nozzle Type	Pressure (kPa)	Height (m)	Speed (km/hr)	Application Rate (L/ha)	Nozzle Orientation (°)	Temp. (°C)	Wind Speed (km/hr)	RH (%)
1	May 15	Bell 206B Helicopter	D7-45	173	18.3	128	18.6	45	2	0-2	92
2	June 11	Bell 206B Helicopter	D2-13	276	9.2	112	9.3	45	21	8-13	41
4	June 16	Cessna 188 Ag Truck	Micronair AU 4000	276	9.1	178	6.0	0	12	4	54
5	June 19	Cessna 188 Ag Truck	Micronair AU 4000	276	--*	--*	6.0**	--*	14	0-8	68

*Data not available.

**It was assumed for recovery calculations to be the same as in the calibration run (set 4).

Table 2. Droplet Size Data.

Set	Spread* Factor	VMD ($D_{V0.5}$) (microns)	NMD (microns)	Recovery** (%)	$D_{V0.1}$ (microns)	$D_{V0.9}$ (microns)	Relative Span	Drops per cm^2 (Average)
1	0.66	770	265	94	350	970	0.81	4.0
2	0.66	285	209	20	200	425	0.79	2.7
4	0.58	276	159	152	165	410	0.89	19.1
5	0.56	304	179	43	170	390	0.72	4.4

*Defined as the ratio of drop diameter to stain diameter.

**Calculated from (total volume ÷ area) as counted on the Quantimet 970 and compared to the nominal application rate (Table 1).

(by volume and number) less than the stated diameter. Using these graphs one can easily obtain data on the driftable fraction and the uniformity of the deposit. Tables 3 to 6 tabulate the calculations necessary to construct the above graphs. In Tables 4 and 5 a calculation of the amount of active ingredient per area is done using 38% active ingredient. For example, set 4 shows a deposit of 345 mg/m^2 of active ingredient, equivalent to 3.45 L/ha. The strength of the B.t. formulation used was 12.5 billion international units (BIU) per litre, resulting in 43 BIU/ha applied compared to the nominal rate of 30 BIU/ha.

Figures 9 to 11 show the number of $drops/cm^2$ plotted against the downwind distance, where 0 represents the centre line of aircraft flight. The graphs are of marginal use only as more cards spaced closer together would better delineate the spray distribution.

Appendix I contains the detailed analysis of each Kromekote card set, as needed to calculate the integrated compilations and aircraft distribution patterns.

Figure 1. **Drop Distribution by Number (Set 1)**

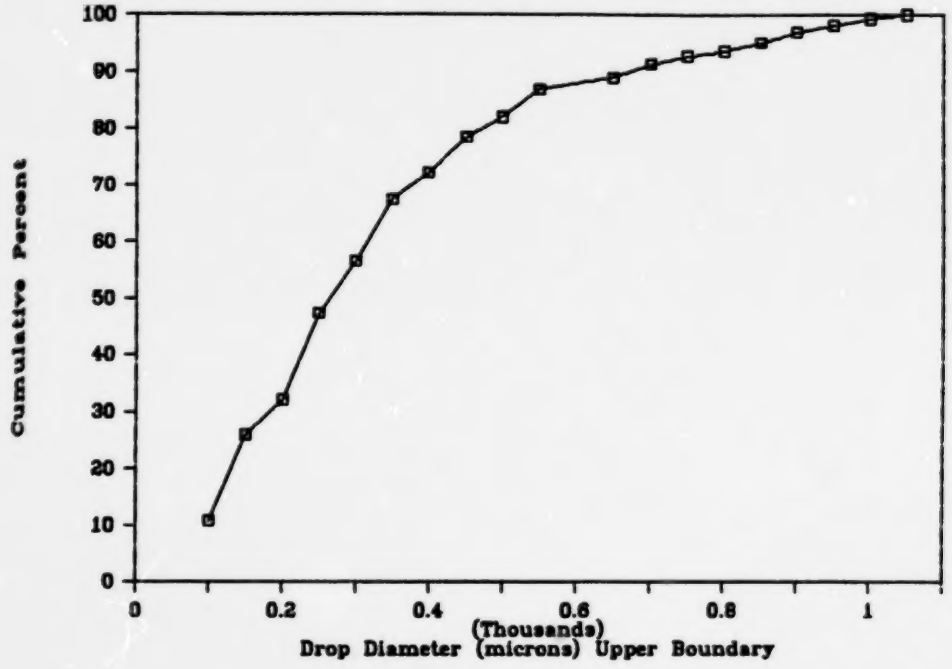

Figure 2. **Drop Distribution by Volume (Set 1)**

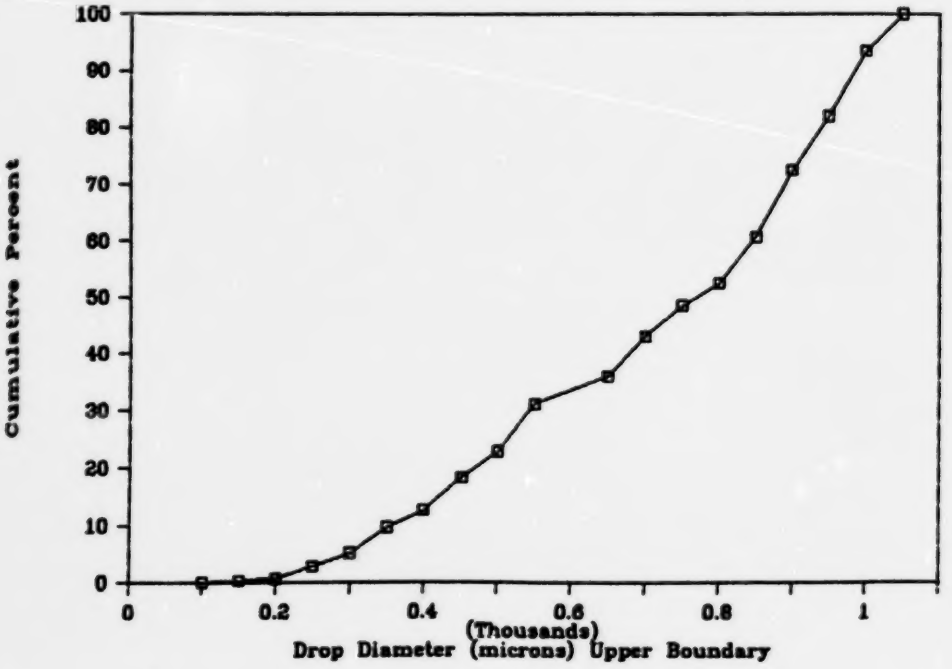

Table 3. Spray Image SET-1

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	36	10.7	0.0080	0.1
100 - 150	51	25.9	0.0522	0.4
150 - 200	21	32.1	0.0589	0.8
200 - 250	51	47.3	0.3042	2.9
250 - 300	31	56.5	0.3376	5.2
300 - 350	37	67.6	0.6650	9.7
350 - 400	16	72.3	0.4418	12.7
400 - 450	21	78.6	0.8441	18.4
450 - 500	12	82.1	0.6734	23.0
550 - 550	16	86.9	1.2123	31.2
600 - 650	7	89.0	0.6968	35.9
650 - 700	8	91.4	1.0227	42.9
700 - 750	5	92.9	0.8052	48.3
750 - 800	3	93.7	0.5986	52.4
800 - 850	5	95.2	1.2186	60.7
850 - 900	6	97.0	1.7641	72.6
900 - 950	4	98.2	1.4031	82.2
950 - 1000	4	99.4	1.6576	93.4
1000 - 1050	2	100.0	0.9706	100.0
	336		14.7345	

No. median diam. = 265 microns
Vol. median diam. = 770 microns
Drops/sq. cm. = 4.0

Figure 3. Drop Distribution by Number (Set 2)

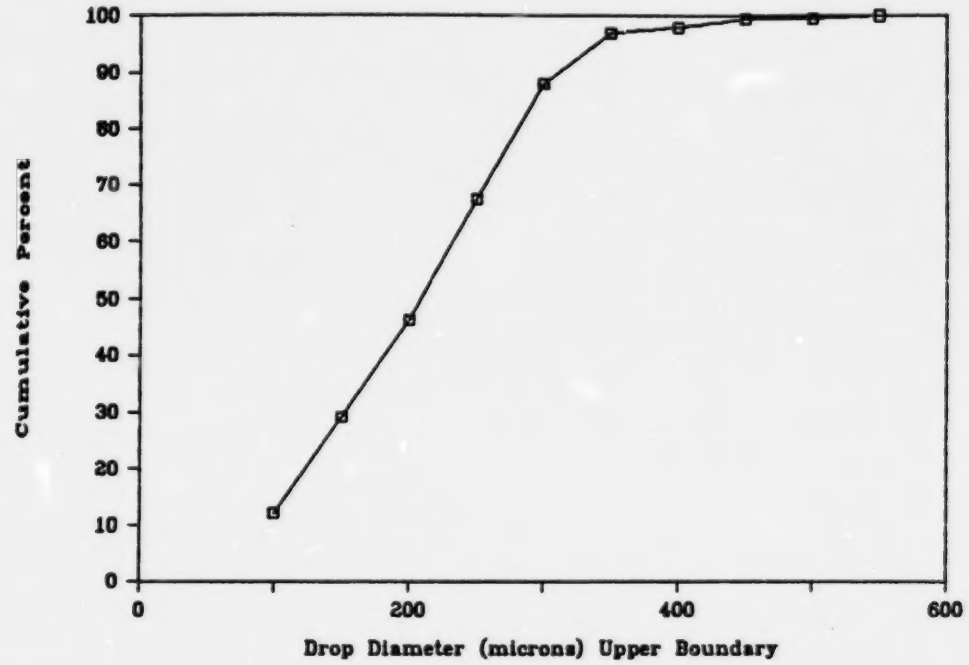

Figure 4. Drop Distribution by Volume (Set 2)

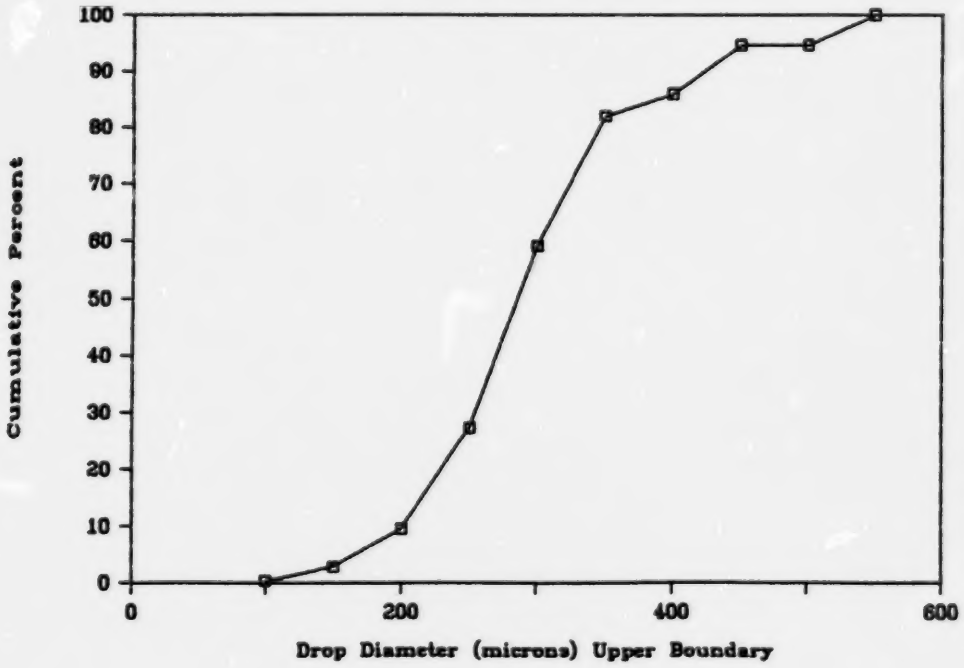

Table 4. Spray Image SET-2

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	24	12.1	0.0053	0.4
100 - 150	34	29.1	0.0348	2.8
150 - 200	34	46.2	0.0954	9.6
200 - 250	42	67.3	0.2505	27.4
250 - 300	41	87.9	0.4465	59.1
300 - 350	18	97.0	0.3235	82.1
350 - 400	2	98.0	0.0552	86.1
400 - 450	3	99.5	0.1206	94.6
450 - 500	0	99.5	0.0000	94.6
500 - 550	1	100.0	0.0758	100.0
	199		1.4075	

No. median diam. = 209 microns
Vol. median diam. = 285 microns
Drops/sq. cm. = 2.7

Figure 5. Drop Distribution by Number (Set 4)

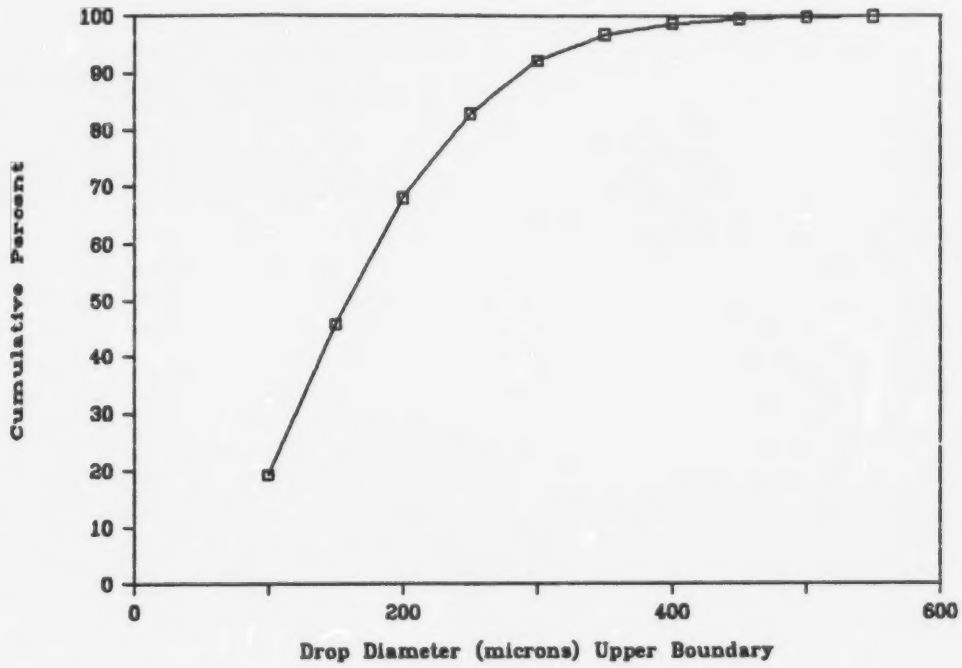

Figure 6. Drop Distribution by Volume (Set 4)

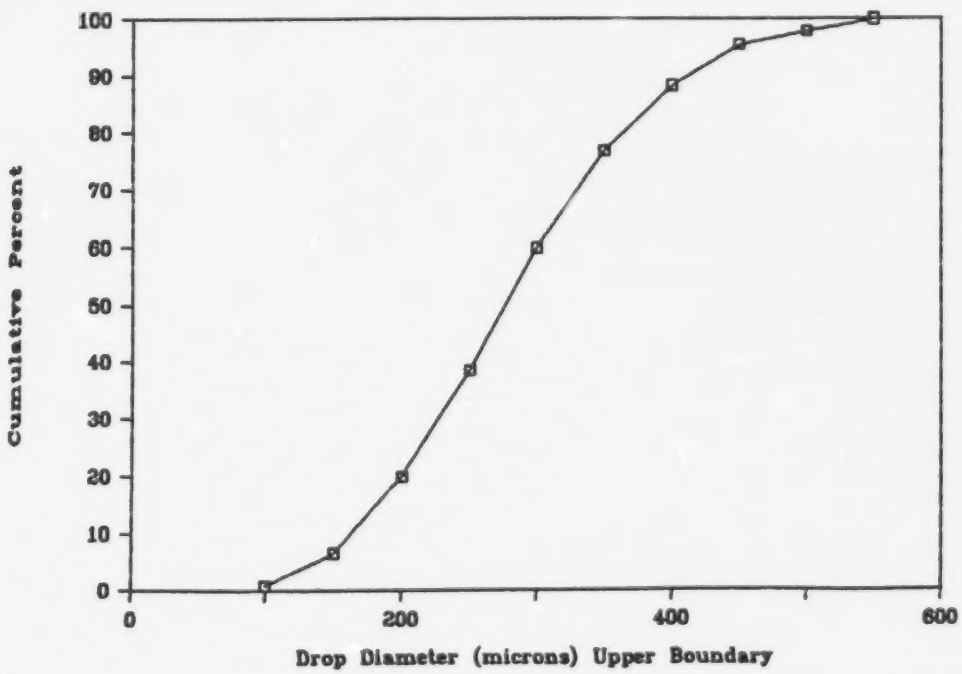

Table 5. Spray Image SET-4

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	293	19.3	0.0647	0.9
100 - 150	402	45.8	0.4111	6.6
150 - 200	339	68.1	0.9513	19.7
200 - 250	225	82.9	1.3419	38.3
250 - 300	142	92.3	1.5463	59.7
300 - 350	69	96.8	1.2402	76.9
350 - 400	30	98.8	0.8284	88.3
400 - 450	13	99.7	0.5225	95.6
450 - 500	3	99.9	0.1683	97.9
500 - 550	2	100.0	0.1515	100.0
	1518		7.2263	

No. median diam.	=	159 microns
Vol. median diam.	=	276 microns
Aplication (mg/sq m) at 38% act. ing.	=	345.3
Drops/sq. cm.	=	19.1

Figure 7. **Drop Distribution by Number (Set 5)**

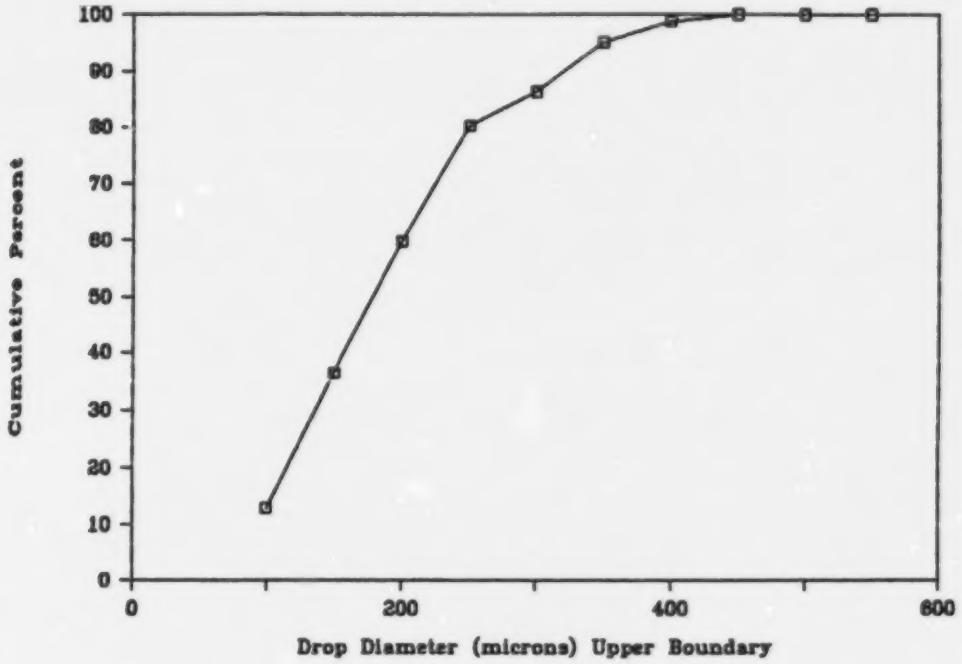

Figure 8. **Drop Distribution by Volume (Set 5)**

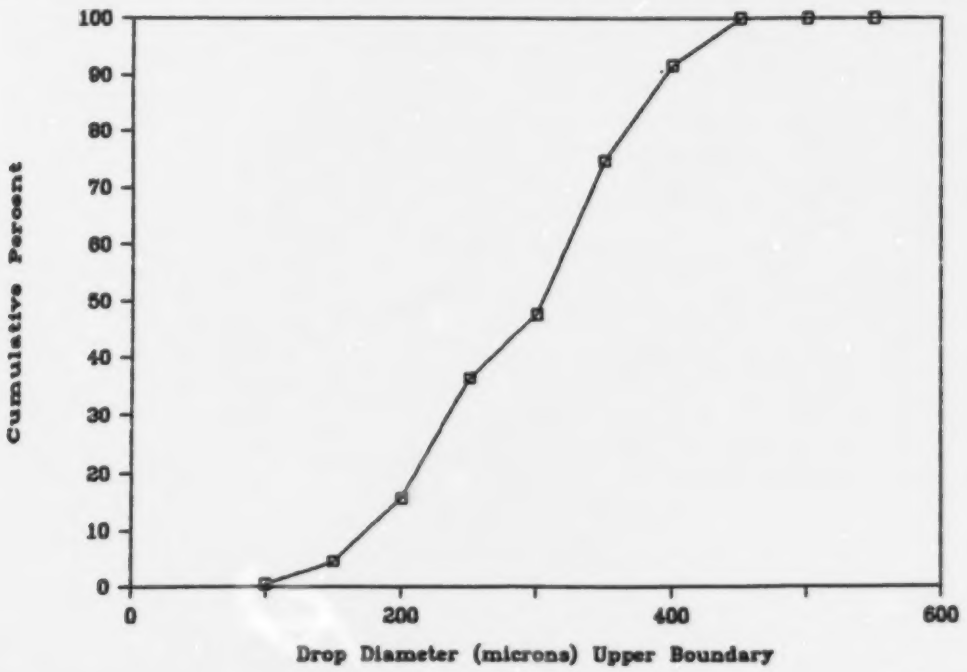

Table 6. Spray Image SET-5

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	32	12.9	0.0071	0.5
100 - 150	59	36.5	0.0603	4.6
150 - 200	58	59.8	0.1628	15.7
200 - 250	51	80.3	0.3042	36.5
250 - 300	15	86.3	0.1633	47.7
300 - 350	22	95.2	0.3954	74.8
350 - 400	9	98.8	0.2485	91.8
400 - 450	3	100.0	0.1206	100.0
450 - 500	0	100.0	0.0000	100.0
500 - 550	0	100.0	0.0000	100.0
	249		1.4622	

No. median diam.	=	179 microns
Vol. median diam.	=	304 microns
Aplication (mg/sq m) at 38% act. ing.	=	97.8
Drops/sq. cm.	=	4.4

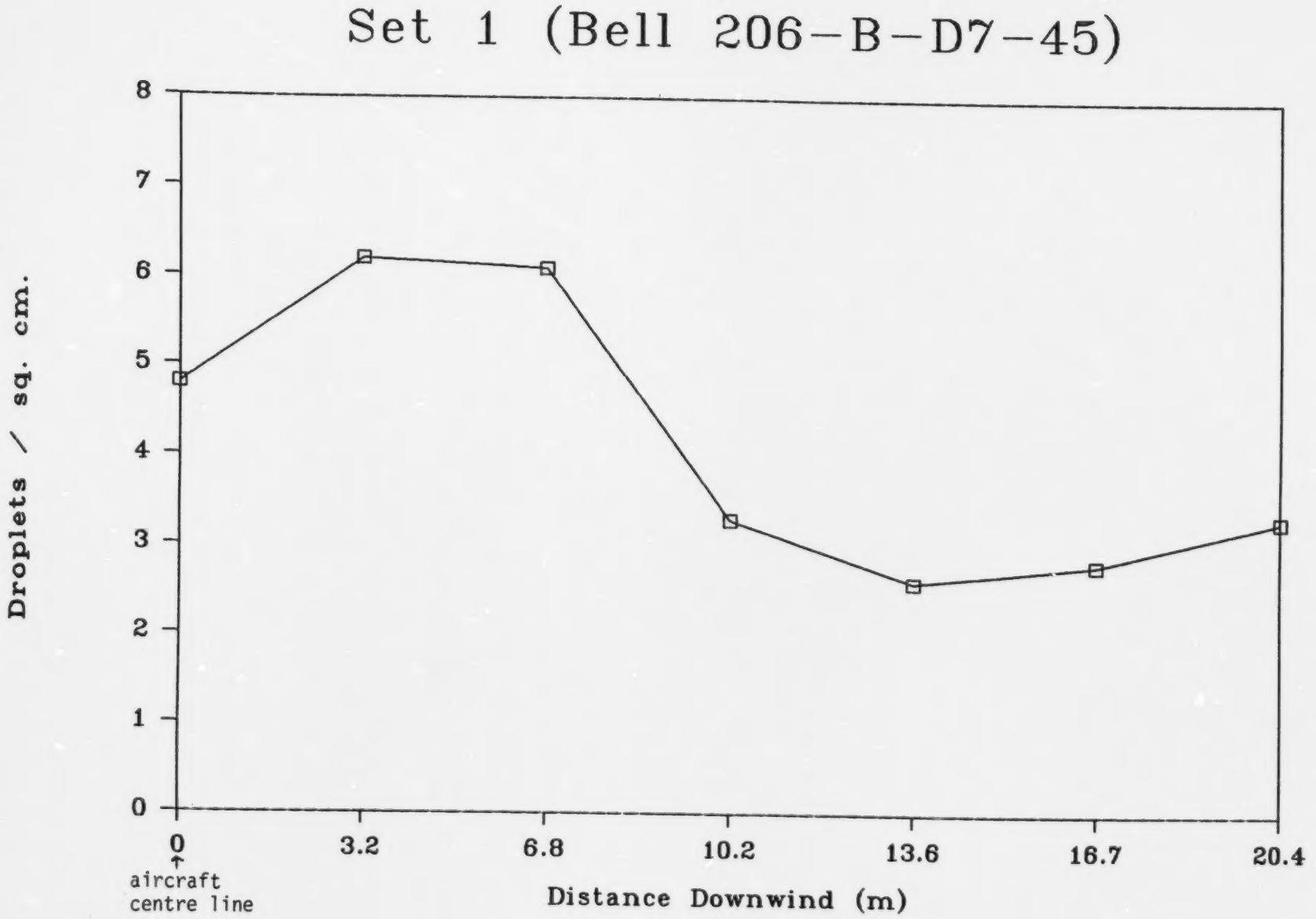

Figure 9. Distribution of Spray Deposit Under Helicopter (Set 1).

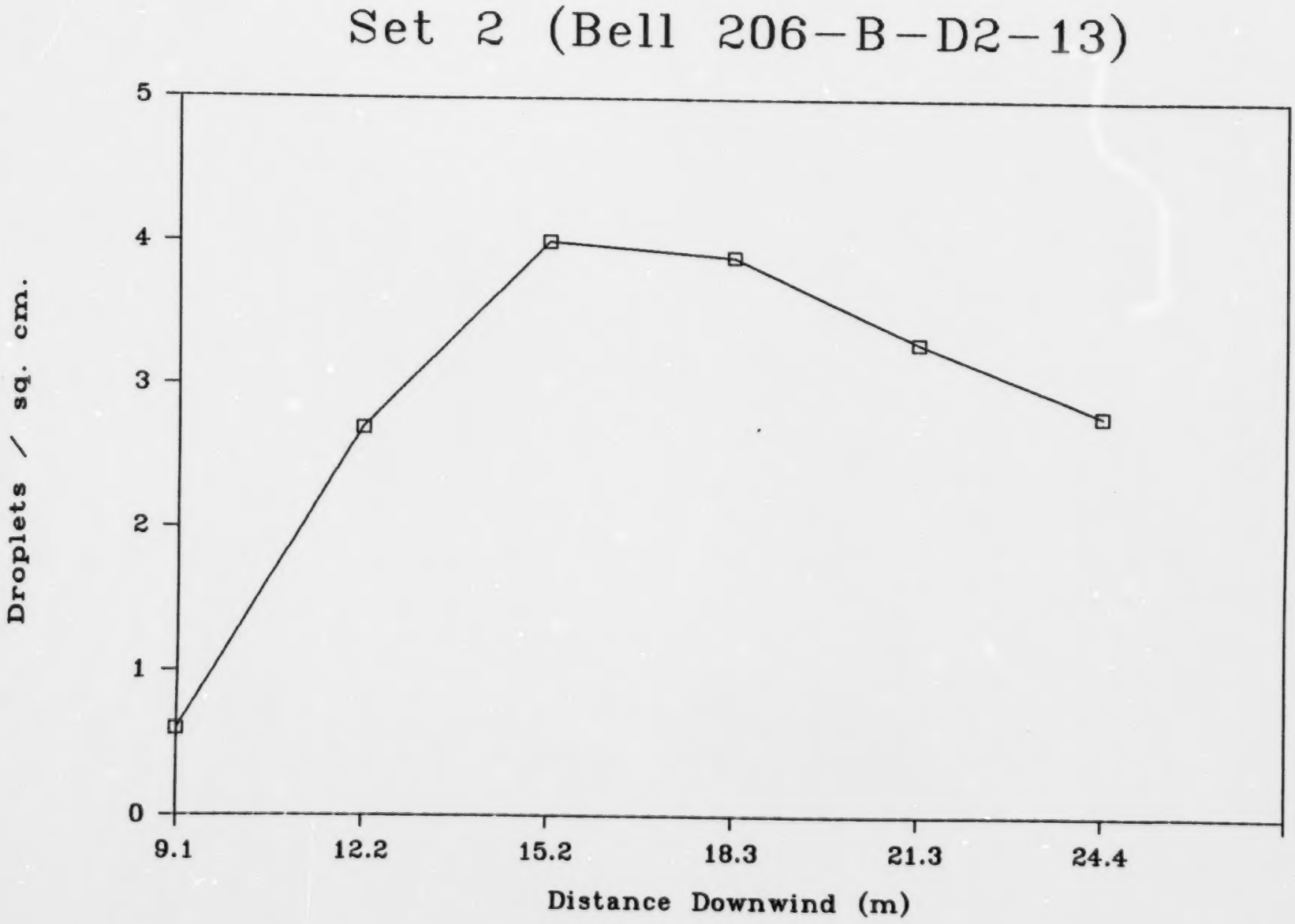

Figure 10. Distribution of Spray Deposit Under Helicopter (Set 2).

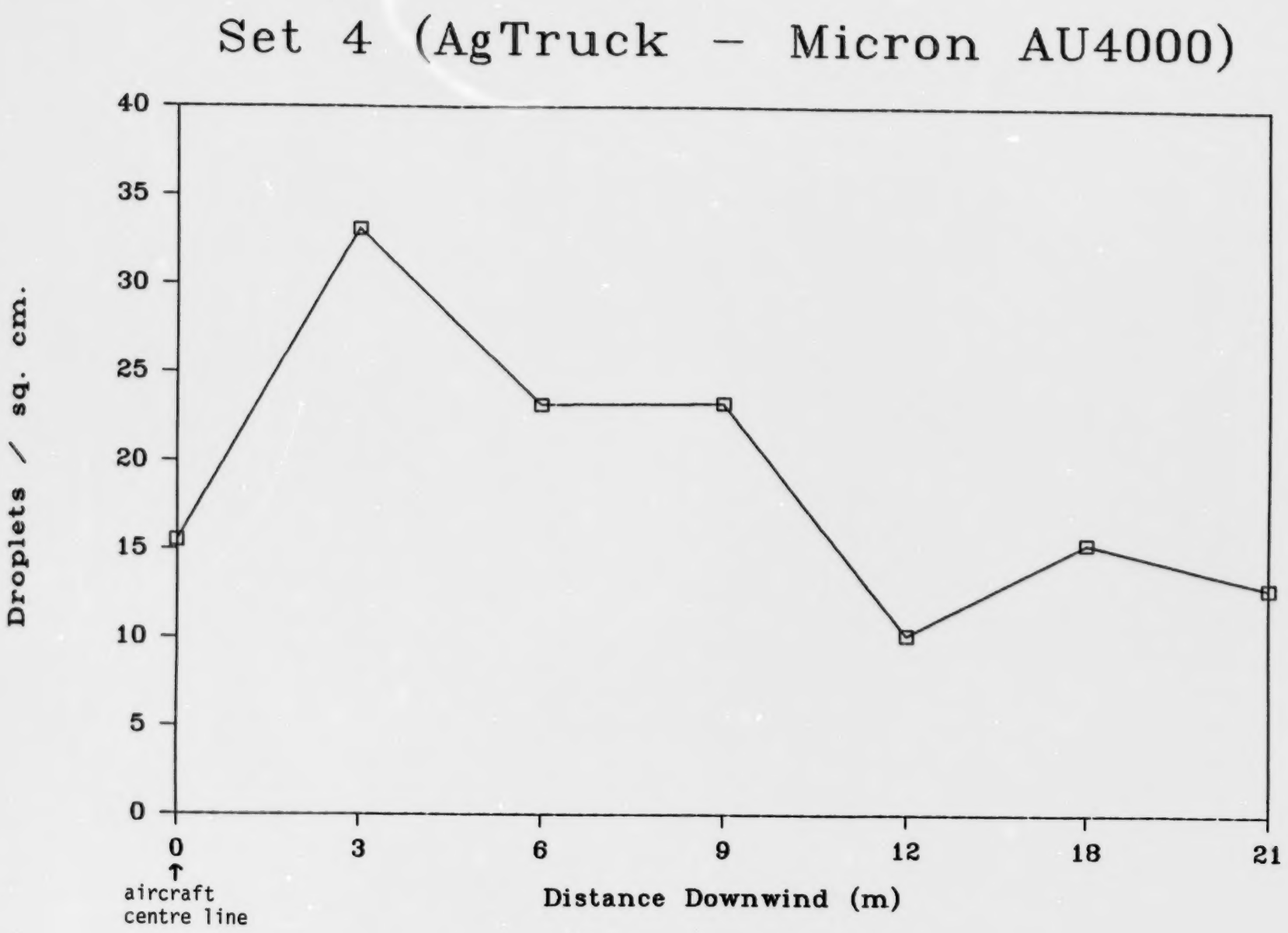

Figure 11. Distribution of Spray Deposit Under Cessna 188B (Set 3).

DISCUSSION

The main factors governing the drop spectrum found from deposit cards are: aircraft parameters including spray height, speed, nozzle type and orientation; weather conditions and the type of foliage sprayed. Each of these factors will be discussed in relation to the data presented.

One must first arrive at a drop frequency before assessment of the data. Cadogen et al. (1986) reported 4.5-12.7 drops/cm^2 using similar micronair rotary atomizer nozzles (sets 4 and 5), although the application rates were lower by a factor of 0.75. Fisher and Menzies (1976) suggest 35 drops/cm^2 (215 µm) best immobilize the oriental fruit moth larvae while Ciba-Geigy (Anonymous 1975) recommend 20 drops/cm^2 for good general insect control. In an earlier publication (Anonymous 1973) 100 drops/cm^2 was suggested as a drop frequency. The latter figure is not realistic when one uses spray volumes of 6-20 L/ha. It is the author's viewpoint that one should aim for a minimum of 20 drops/cm^2 in an open field calibration run to ensure proper coverage for insect control.

The second task is to arrive at a suitable VMD that gives adequate coverage for good insect control.

The generally accepted size range for good control is in the 20-60 µm range (Barry et al. 1977; Sundaram et al. 1986). Johnstone (1971) has suggested a VMD of approximately 200 µm for low volume spraying (20-50 L/ha) by air and he has put limitations on delivery height and wind speed (in agricultural applications). For forestry spraying one should aim at VMD's of approximately 100 µm for effective control of the western spruce budworm.

The first set of cards shows a large VMD of 770 µm which gives good recovery (94%) and low drift potential but results in a very poor and ineffective coverage pattern for insect control. The average drop frequency is inadequate at only 4/cm^2. The effective swath width from an analysis of Figure 9 would appear to be approximately 14 m. The weather conditions favored low evaporation rates of droplets due to the low temperature (2°C) and high RH (92%). The low wind speed (0-2 km/hr) would aid in minimizing airborne drift.

In the second set the D2-13 nozzle selection produced a much finer spray of 285 µm VMD at the higher pressure setting. The higher temperature (21°C), lower RH (41%) and higher winds (8-13 km/hr) would all contribute to increased drift. The application rate was half that of set 1. It must be kept in mind that Yates et al. (1985) measured the droplet spectrums at the nozzle using a laser scanning system. We have measured the drop spectrum after partial drift and evaporative losses have occurred. Therefore, the definition of spray volume $\leq$150 µm as a measure of drift, although useful in a relative sense, does not have the same meaning as if measured at the nozzle. The same argument holds true for relative span calculations. The low recovery of 20% in set 2 could be due to large losses of material caused by drift and evaporation as the frequency of drops was only 1.7/cm^2. Not enough information is given to make an accurate prediction of swath width for set 2 from Figure 10.

The penetration of spray material could be greatly increased by using slower forward speeds when spraying by helicopter. Parkin (1979) has shown that rotor downwash velocity rapidly drops off as air speed increases. The optimum air speed may be in the range of 20-40 km/hr.

On the other hand, as air speed is reduced a different selection of nozzles may be appropriate for delivery of the correct drop size spectrum (perhaps a rotary atomization system).

In set 4 the drop frequency was essentially adequate, averaging 19.1 drops/cm^2 while the VMD was 276 µm. The nominal application rate dropped to 6 L/ha as micronair rotary atomizers were used. Weather conditions favored low to moderate evaporation and drift conditions 12°C, 4 km/hr and 54% RH. Using the volume of drops deposited per area an application rate of 9.1 L/ha was calculated. It is entirely possible in a field situation to have higher or lower delivery rates than the nominal settings. The best overall deposit was produced from this set of Kromekote cards. Figure 11 indicated the swath width would be 22 m, determined by finding the downwind distance corresponding to 15 drops/cm^2, then multiplying by a factor of two.

The drop frequency from set 5 is not adequate if the cards were set out in an open area, neglecting the effect of foliage. A complete set of operating parameters was unavailable, so further comment would be only speculation.

All the sets produced relative spans of less than unity. According to Yates et al. (1985) when measuring the nozzle droplet spectrum with a laser system, if the relative span is less than one the VMD is usually less than 200 µm. Conversely the relative span usually exceeds one for larger VMD's, indicating a wider spectrum of droplet sizes. However, several factors may hinder a direct comparison to Yates et al. (1985) data. The most obvious is that the laser counted droplets at the source of production compared to the deposited spectrum after drift and evaporation have occurred. Secondly, Yates et al. (1985) started their counts

at 28 µm drop size whereas we start at 50 µm drop diameter. In order to compare field drop depositions using relative span more information should be available.

The technique of using a photocopy from a Kromekote card produces images that are slightly magnified, and do not have well defined edges on the microscopic level. The resulting images analyzed may be biased on the high side. It is, therefore, recommended to use either a more concentrated rhodamine B solution (0.025% by weight) or a different type of deposition card. We have found that Kodak Kodabromide paper treated with a pH indicator responds very well to water based sprays (Wallace and Yoshida 1977). Using photo indicator paper the lower limit for drop size detection is 25 µm. The need to add a dye to the tank is eliminated when using this paper, as water responds directly when in contact with the surface.

One of the main factors influencing canopy deposition and drift fraction beyond 400 m is release height and secondly atmospheric stability (Picot et al. 1986). In order to reduce unwanted drift it would be best to spray in the early morning. The aircraft should be at a height just above the forest canopy while maintaining a margin for safe operation.

RECOMMENDATIONS

1. In order to obtain the best insect-droplet canopy interaction, slow flying (20-40 km/hr) helicopters utilizing maximum rotor downwash could be used, with the boom width not extending beyond the rotor diameter.

2. If a large area is to be sprayed a fixed wing aircraft can be used equipped with a fine nozzle setup (Micronair type). In some cases it may be necessary to spray the area twice. Due to economic reasons fixed wing aircraft are usually chosen for large spray areas.

3. The frequency of drop deposition should be $\geq$20 drops/cm^2 in open field calibration tests to ensure proper coverage. The spray should have a VMD of approximately 100 µm which balances the effects of drift and proper size for insect coverage. Larger size droplets (approximately 100 µm) will break up when contacting the foliage and redistribute to smaller drop sizes which have greater deposition on conifer needles.

4. For a more complete analysis of swath widths cards should be placed at intervals of 2.5 m on both sides of the flight centre line, extending at least 30 m on either side. A stronger rhodamine B solution or a different type of deposition card should be used to produce more distinct images. The limit of detection could be lowered from 50 µm to 25 µm drop diameter if the alternate cards were used.

5. Keeping the spray height close to the top forest canopy would help in reducing drift, as would spraying during times of neutral stability conditions.

6. Through an intense calibration procedure the correct deposition and spray size should be achieved before spraying a forest area. Through a combination of nozzle orientation, aircraft speed and delivery rate, proper deposition can be achieved.

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APPENDIX I

RAW DATA OF INDIVIDUAL KROMEKOTE CARDS

Set 1

Spray Image CENTER

Diam. class (microns)	Count	Acc. % (by no.)	Volwme (microl.)	Acc. % (by vol)
100 - 150	2	3.7	0.0020	0.2
150 - 200	3	9.3	0.0084	1.2
200 - 250	14	35.2	0.0835	10.5
250 - 300	20	72.2	0.2178	34.7
300 - 350	8	87.0	0.1438	50.7
350 - 400	1	88.9	0.0276	53.7
400 - 450	2	92.6	0.0804	62.7
450 - 500	1	94.4	0.0561	6>.9
500 - 550	2	98.1	0.1515	85.8
600 - 650	1	100.0	0.1278	100.0
	54		0.8990	

No. median diam. = 270 microns
Vol. median diam. = 348 microns

Drops/sq. cm. = 4.8

Spray Image D3.2

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 150	19	27.1	0.0099	0.2
150 - 250	19	54.3	0.0796	1.7
250 - 350	11	70.0	0.1555	4.8
350 - 450	9	82.9	0.3016	10.6
450 - 550	0	82.9	0.0000	10.6
550 - 650	1	84.3	0.1131	12.8
650 - 750	2	87.1	0.3592	19.8
750 - 850	6	95.7	1.6085	50.9
850 - 950	2	98.6	0.7634	65.7
950 - 1050	0	98.6	0.0000	65.7
1050 - 1150	0	98.6	0.0000	65.7
1150 - 1250	0	98.6	0.0000	65.7
1250 - 1350	0	98.6	0.0000	65.7
1350 - 1450	0	98.6	0.0000	65.7
1450 - 1550	1	100.0	1.7672	100.0
	70		5.1580	

No. median diam.	=	234	microns
Vol. median diam.	=	847	microns
Drops/sq. cm.	=	6.2	

Spray Image D3.6

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % by vol)
50 - 100	4	16.0	0.0009	.0
150 - 200	1	20.0	0.0028	0.2
250 - 300	1	24.0	0.0109	0.8
300 - 350	2	32.0	0.0359	2.6
350 - 400	3	44.0	0.0828	6.9
400 - 450	5	64.0	0.2010	17.3
450 - 500	2	72.0	0.1122	23.1
500 - 550	1	76.0	0.0758	27.0
600 - 650	2	84.0	0.2557	40.2
650 - 700	1	88.0	0.1610	48.5
800 - 850	1	92.0	0.2940	63.7
850 - 900	2	100.0	0.7015	100.0
	25		1.9346	

No. median diam. = 415 microns
Vol. median diam. = 713 microns

Drops/sq. cm. = 2.2

Spray Image D6.8

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 150	22	31.9	0.0115	0.3
150 - 250	12	49.3	0.0503	1.4
250 - 350	8	60.9	0.1131	4.1
350 - 450	4	66.7	0.1340	7.2
450 - 550	14	87.0	0.9163	28.5
550 - 650	1	88.4	0.1131	31.1
650 - 750	1	89.9	0.1796	35.3
750 - 850	3	94.2	0.8042	53.9
850 - 950	2	97.1	0.7634	71.7
950 - 1050	1	98.6	0.5236	83.8
1050 - 1150	1	100.0	0.6969	100.0
	69		4.3061	

No. median diam. = 256 microns
Vol. median diam. = 828 microns

Drops/sq. cm. = 6.1

Spray Image D10.2

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	3	8.1	0.0007	.0
100 - 150	5	21.6	0.0051	0.3
150 - 200	6	37.8	0.0168	1.0
200 - 250	4	48.6	0.0239	2.2
250 - 300	1	51.4	0.0109	2.7
300 - 350	3	59.5	0.0539	5.2
350 - 400	2	64.9	0.0552	7.7
450 - 500	2	70.3	0.1122	12.9
500 - 550	2	75.7	0.1515	19.9
550 - 600	2	81.1	0.1991	29.1
600 - 650	2	86.5	0.2557	41.0
650 - 700	2	91.9	0.3221	55.9
750 - 800	1	94.6	0.2437	67.2
800 - 850	1	97.3	0.2940	80.8
900 - 950	1	100.0	0.4144	100.0
	37		2.1592	

No. median diam. = 275 microns
Vol. median diam. = 680 microns

Drops/sq. cm. = 3.3

Spray Image D13.6

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	2	6.7	0.0004	.0
100 - 150	7	30.0	0.0072	0.7
150 - 200	3	40.0	0.0084	1.5
200 - 250	4	53.3	0.0239	3.8
250 - 300	1	56.7	0.0109	4.9
300 - 350	4	70.0	0.0719	11.8
350 - 400	2	76.7	0.0552	17.1
500 - 550	1	80.0	0.0758	26.4
550 - 600	3	90.0	0.2986	53.1
600 - 650	1	93.3	0.1278	65.4
650 - 700	1	96.7	0.1610	80.8
700 - 750	1	100.0	0.1995	100.0
	30		1.0407	

No. median diam. = 238 microns
Vol. median diam. = 594 microns

Drops/sq. cm. = 2.6

Spray Image D16.7

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	1	7.1	0.0002	0.1
150 - 200	1	14.3	0.0028	1.0
200 - 250	3	35.7	0.0179	7.2
250 - 300	2	50.0	0.0218	14.6
300 - 350	3	71.4	0.0539	33.1
350 - 400	2	85.7	0.0552	52.1
400 - 450	1	92.9	0.0402	65.9
550 - 600	1	100.0	0.0995	100.0
	14		0.2916	

No. median diam. = 300 microns
Vol. median diam. = 394 microns

Drops/sq. cm. = 2.8

Spray Image D20.4

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	13	34.2	0.0029	0.5
100 - 150	9	57.9	0.0092	2.1
150 - 200	2	63.2	0.0056	3.1
250 - 300	1	65.8	0.0109	5.0
300 - 350	3	73.7	0.0539	14.4
350 - 400	3	81.6	0.0828	28.8
400 - 450	3	89.5	0.1206	49.9
450 - 500	2	94.7	0.1122	69.4
500 - 550	1	97.4	0.0758	82.6
550 - 600	1	100.0	0.0995	100.0
	38		0.5735	

No. median diam. = 133 microns
Vol. median diam. = 450 microns

Drops/sq. cm. = 3.3

Set 2

Spray Image C3.30

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 70	1	10.0	0.0001	.0
70 - 90	2	30.0	0.0005	.0
130 - 150	1	40.0	0.0014	0.1
190 - 210	1	50.0	0.0042	0.3
250 - 270	1	60.0	0.0092	0.8
310 - 330	1	70.0	0.0172	1.7
390 - 410	1	80.0	0.0335	3.5
510 - 530	1	90.0	0.0736	7.3
1490 - 1510	1	100.0	1.7672	100.0
	10		1.9069	

No. median diam. = 200 microns
Vol. median diam. = 858 microns

Drops/sq. cm. = 0.6

Spray Image C3.40

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
90 - 110	1	3.2	0.0005	0.1
230 - 250	2	9.7	0.0145	3.1
250 - 270	2	16.1	0.0184	6.9
270 - 290	7	38.7	0.0805	23.5
290 - 310	5	54.8	0.0707	38.0
310 - 330	5	71.0	0.0858	55.7
330 - 350	6	90.3	0.1235	81.2
350 - 370	1	93.5	0.0244	86.2
390 - 410	2	100.0	0.0670	100.0
	31		0.4853	

No. median diam. = 294 microns
Vol. median diam. = 323 microns

Drops/sq. cm. = 2.7

Spray Image C3.50

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	1	2.2	0.0001	.0
100 - 125	2	6.5	0.0015	0.5
175 - 200	7	21.7	0.0244	7.5
200 - 225	9	41.3	0.0455	20.6
225 - 250	10	63.0	0.0706	41.0
250 - 275	8	80.4	0.0762	62.9
275 - 300	7	95.7	0.0876	88.2
300 - 325	1	97.8	0.0161	92.8
350 - 375	1	100.0	0.0250	100.0
	46		0.3470	

No. median diam. = 225 microns
Vol. median diam. = 260 microns

Drops/sq. cm. = 4.0

Spray Image C3.60

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	6	13.6	0.0008	0.4
100 - 125	5	25.0	0.0038	2.5
125 - 150	5	36.4	0.0069	6.2
150 - 175	6	50.0	0.0136	13.6
175 - 200	4	59.1	0.0139	21.2
200 - 225	5	70.5	0.0253	34.9
225 - 250	4	79.5	0.0282	50.2
250 - 275	7	95.5	0.0667	86.4
275 - 300	2	100.0	0.0250	100.0
	44		0.1842	

No. median diam. = 175 microns
Vol. median diam. = 250 microns

Drops/sq. cm. = 3.9

Spray Image C3.70

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	2	5.4	0.0003	0.4
100 - 125	6	21.6	0.0021	3.7
125 - 150	5	35.1	0.0038	9.5
150 - 175	10	62.2	0.0138	30.5
175 - 200	7	81.1	0.0159	54.8
200 - 225	5	94.6	0.0174	81.4
225 - 250	1	97.3	0.0051	89.2
250 - 275	1	100.0	0.0071	100.0
	37		0.0653	

No. median diam. = 164 microns
Vol. median diam. = 195 microns

Drops/sq. cm. = 3.3

Spray Image C3.80

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	4	12.5	0.0005	0.4
75 - 100	2	18.8	0.0007	0.9
100 - 125	4	31.3	0.0030	2.9
125 - 150	1	34.4	0.0014	3.9
150 - 175	2	40.6	0.0045	7.0
175 - 200	3	50.0	0.0104	14.2
200 - 225	6	68.8	0.0304	35.2
225 - 250	3	78.1	0.0212	49.8
250 - 275	5	93.8	0.0476	82.7
275 - 300	2	100.0	0.0250	100.0
	32		0.1448	

No. median diam. = 200 microns
Vol. median diam. = 250 microns

Drops/sq. cm. = 2.8

Set 4

Spray Image KNV.0

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	19	10.8	0.0025	0.4
75 - 100	21	22.7	0.0075	1.4
100 - 125	20	34.1	0.0151	3.6
125 - 150	21	46.0	0.0289	7.8
150 - 175	38	67.6	0.0862	20.2
175 - 200	15	76.1	0.0522	27.8
200 - 225	15	84.7	0.0759	38.7
225 - 250	10	90.3	0.0706	48.9
250 - 275	2	91.5	0.0191	51.6
275 - 300	7	95.5	0.0876	64.3
300 - 325	3	97.2	0.0482	71.2
350 - 375	1	97.7	0.0306	75.6
375 - 400	1	98.3	0.0369	81.0
400 - 425	3	100.0	0.1320	100.0
	176		0.6931	

No. median diam.	=	155	microns
Vol. median diam.	=	260	microns
Application (mg/sq m) at 38% act. ing.	=	231.8	
Drops/sq. cm.	=	15.5	

Spray Image KSV.1

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	65	17.3	0.0144	0.9
100 - 150	114	47.6	0.1166	8.2
150 - 200	92	72.1	0.2582	24.3
200 - 250	56	87.0	0.3340	45.2
250 - 300	30	94.9	0.3267	65.7
300 - 350	11	97.9	0.1977	78.0
350 - 400	3	98.7	0.0828	83.2
400 - 450	2	99.2	0.0804	88.2
450 - 500	2	99.7	0.1122	95.3
500 - 550	1	100.0	0.0758	100.0
	376		1.5987	

No. median diam.	=	126	microns
Vol. median diam.	=	261	microns
Application (mg/sq m) at 38% act. ing.	=	534.8	
Drops/sq. cm.	=	33.1	

Spray Image KSV.2

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	26	9.8	0.0034	0.4
75 - 100	40	25.0	0.0143	1.8
100 - 125	44	41.7	0.0332	5.3
125 - 150	33	54.2	0.0454	10.0
150 - 175	28	64.8	0.0635	16.6
175 - 200	28	75.4	0.0974	26.7
200 - 225	15	81.1	0.0759	34.5
225 - 250	16	87.1	0.1129	46.2
250 - 275	15	92.8	0.1429	61.0
275 - 300	4	94.3	0.0500	66.2
300 - 325	5	96.2	0.0803	74.5
325 - 350	7	98.9	0.1415	89.2
350 - 375	1	99.2	0.0306	92.4
375 - 400	2	100.0	0.0738	100.0
	264		0.9651	

No. median diam.	=	142	microns
Vol. median diam.	=	256	microns
Application (mg/sq m) at 38% act. ing.	=	322.8	
Drops/sq. cm.	=	23.2	

Spray Image KSV.3

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	29	10.9	0.0064	0.4
100 - 150	55	31.7	0.0562	3.5
150 - 200	55	52.5	0.1543	12.1
200 - 250	50	71.3	0.2982	28.8
250 - 300	37	85.3	0.4029	51.2
300 - 350	25	94.7	0.4494	76.3
350 - 400	11	98.9	0.3037	93.3
400 - 450	3	100.0	0.1206	100.0
	265		1.7918	

No. median diam.	=	194	microns
Vol. median diam.	=	297	microns
Application (mg/sq m) at 38% act. ing.	=	599.4	
Drops/sq. cm.	=	23.3	

Spray Image KSV.4

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	25	21.6	0.0055	1.5
100 - 150	38	54.3	0.0389	11.9
150 - 200	25	75.9	0.0702	30.8
200 - 250	17	90.5	0.1014	58.0
250 - 300	9	98.3	0.0980	84.4
300 - 350	1	99.1	0.0180	89.2
400 - 450	1	100.0	0.0402	100.0
	116		0.3721	

No. median diam.	=	143	microns
Vol. median diam.	=	234	microns
Application (mg/sq m) at 38% act. ing.	=	124.5	
Drops/sq. cm.	=	10.2	

Spray Image KSV.6

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	46	26.3	0.0102	1.2
100 - 150	44	51.4	0.0450	6.3
150 - 200	39	73.7	0.1094	18.9
200 - 250	18	84.0	0.1074	31.2
250 - 300	14	92.0	0.1524	48.8
300 - 350	7	96.0	0.1258	63.2
350 - 400	1	96.6	0.0276	66.4
400 - 450	4	98.9	0.1608	84.8
450 - 500	1	99.4	0.0561	91.3
500 - 550	1	100.0	0.0758	100.0
	175		0.8705	

No. median diam.	=	147	microns
Vol. median diam.	=	304	microns
Application (mg/sq m) at 38% act. ing.	=	291.2	
Drops/sq. cm.	=	15.4	

Spray Image KSV.7

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	22	15.1	0.0049	0.5
100 - 150	33	37.7	0.0337	4.0
150 - 200	19	50.7	0.0533	9.4
200 - 250	28	69.9	0.1670	26.5
250 - 300	24	86.3	0.2613	53.3
300 - 350	10	93.2	0.1797	71.7
350 - 400	10	100.0	0.2761	100.0
	146		0.9761	

No. median diam.	=	197	microns
Vol. median diam.	=	293	microns
Application (mg/sq m) at 38% act. ing.	=	326.5	
Drops/sq. cm.	=	12.9	

Set 5

Spray Image 2-H-0

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	4	12.5	0.0009	0.2
100 - 150	4	25.0	0.0041	1.1
200 - 250	1	28.1	0.0060	2.4
250 - 300	3	37.5	0.0327	9.6
300 - 350	16	87.5	0.2876	72.9
350 - 400	3	96.9	0.0828	91.2
400 - 450	1	100.0	0.0402	100.0
	32		0.4542	

No. median diam. = 313 microns
Vol. median diam. = 331 microns

Application (mg/sq m)
at 38% act. ing. = 151.9
Drops/sq. cm. = 2.8

Spray Image 10-H-0

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	10	7.9	0.0022	0.3
100 - 150	23	26.0	0.0235	3.6
150 - 200	39	56.7	0.1094	19.1
200 - 250	35	84.3	0.2087	48.7
250 - 300	10	92.1	0.1089	64.1
300 - 350	5	96.1	0.0899	76.9
350 - 400	3	98.4	0.0828	88.6
400 - 450	2	100.0	0.0804	100.0
	127		0.7059	

No. median diam. = 189 microns
Vol. median diam. = 254 microns

Application (mg/sq m)
at 38% act. ing. = 236.1
Drops/sq. cm. = 11.2

Spray Image 62-H-P

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	8	15.1	0.0018	0.8
100 - 150	9	32.1	0.0092	4.8
150 - 200	16	62.3	0.0449	24.4
200 - 250	12	84.9	0.0716	55.7
250 - 300	6	96.2	0.0653	84.3
300 - 350	2	100.0	0.0359	100.0
	53		0.2287	

No. median diam.	=	180 microns
Vol. median diam.	=	240 microns
Application (mg/sq m) at 38% act. ing.	=	76.5
Drops/sq. cm.	=	4.7

Spray Image 11-D-H

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 100	5	18.5	0.0011	0.8
100 - 150	9	51.9	0.0092	7.6
150 - 200	7	77.8	0.0196	22.1
200 - 250	2	85.2	0.0119	30.9
250 - 300	1	88.9	0.0109	38.9
350 - 400	3	100.0	0.0828	100.0
	27		0.1356	

No. median diam.	=	147	microns
Vol. median diam.	=	316	microns
Application (mg/sq m) at 38% act. ing.	=	45.4	
Drops/sq. cm.	=	2.4	

Spray Image 11-P-H

Diam. class (microns)	Count	Acc. % (by no.)	Volume (microl.)	Acc. % (by vol)
50 - 75	4	25.0	0.0005	2.8
75 - 100	4	50.0	0.0014	10.3
100 - 125	1	56.3	0.0008	14.2
125 - 150	4	81.3	0.0055	43.2
150 - 175	1	87.5	0.0023	55.1
175 - 200	1	93.8	0.0035	73.4
200 - 225	1	100.0	0.0051	100.0
	16		0.0190	

No. median diam.	=	100 microns
Vol. median diam.	=	164 microns
Application (mg/sq m) at 38% act. ing.	=	6.4
Drops/sq. cm.	=	1.4